U. S. FOREST SERVICE

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LAKE STATES FOREST EXPERIMENT STATION • U. S. DEPARTMENT OF AGRICULTURE

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Frost Penetration and Trafficability in Two Peats as Affected by Snowpack and Surface Mosses[1]

Unfrozen peat soils are notoriously poor surfaces for supporting vehicular traffic. In the Lake States, logging operations on peatlands are almost always delayed until winter; then light bulldozers snowplow temporary winter roads, so that they can freeze into hard roadbeds.

To follow the regime of peat-soil freezing and thawing under conditions of snowpacking and snow removal, as well as in undisturbed snow, two swamps about 6 miles south of Rhinelander, Wis., were selected for study during the winter of 1953-54. One was a shallow forested woody peat 1 to 2 feet deep; the other was a forested spaghnum peat 6 to 10 feet deep.

These swamp types, when not frozen, are nontrafficable for all conventional wheeled vehicles, and for all except very light tracked vehicles like weasels, bombardiers, and light crawler tractors.

Site Descriptions

The forested woody peat site had a thin mat of live surface mosses. Successive layers below this were 6 inches of coarse black peat, 6 inches of fine black woody peat, up to 18 inches of fine-textured dark brown peat, and finally a dark yellowish-brown, coarse, sandy soil. This site supported a heavy growth of black spruce 20 to 24 feet tall and tamarack 30 to 35 feet tall, with a scattering of white pine and alder near the edge of the swamp.

The forested sphagnum peat site was covered with a thick layer of coarse, undecomposed or only slightly decomposed sphagnum mosses to a depth of 18 to 24 inches. The surface cover included a growth of leatherleaf, blueberry, and Labradortea, and a scattered stand of stunted 3- to 8-foot-tall black spruce and 4- to 12-foot-tall tamarack.

The presence of shallow water tables, along with the capillary rise, is a factor that keeps peatlands soft and reduces their trafficability. It is also a factor that delays hard freezing. Water tables on selected dates during the winter 1953-54 varied as follows in number of feet below the surface at each site:

Forested woody peat		*Forested sphagnum peat*	
December 4	1.20	December 10	1.68
December 15	1.00	January 15	1.64
January 25	1.04	February 10	1.76
February 10	1.04	March 4	1.42
March 31	1.06	April 5	.62
April 9	.78	April 7	.00
April 23	.43	April 16	.00
April 28	.69	April 28	.20

Temperature Conditions

Average monthly air temperatures (mean of maximum plus minimum) in degrees Fahrenheit in standard Weather Bureau instrument shelters during the study period and the normal temperatures (based on Weather Bureau records to that date) were as follows:

Month	*During study period*	*Normal*
November	35.8	29.7
December	20.5	16.8
January	10.6	10.5
February	24.0	12.8
March	24.4	26.8
April	41.2	40.1
May	46.9	53.2

There were 165 days with freezing weather, and on 31 days the temperature dropped to 0° F. or lower. Cumulative degree days below 32° F. were as follows on the first and sixteenth of each month:

Month	*1st of month*	*16th of month*
December	74	185
January	435	741
February	1,093	1,254
March	1,327	1,515
April	1,608	1,532

The peak of degree days of cold was 1,662 on April 4; by April 30 thawing had progressed so far that the value for degree days was only 1,358.

[1] *Credit is due John L. Thames, Robert Tobiaski, and Edmond I. Swensen of the U.S. Forest Service for assistance in some field aspects of this study and to the Waterways Experiment Station, U.S. Corps of Engineers, Vicksburg, Miss., for financing part of the study.*

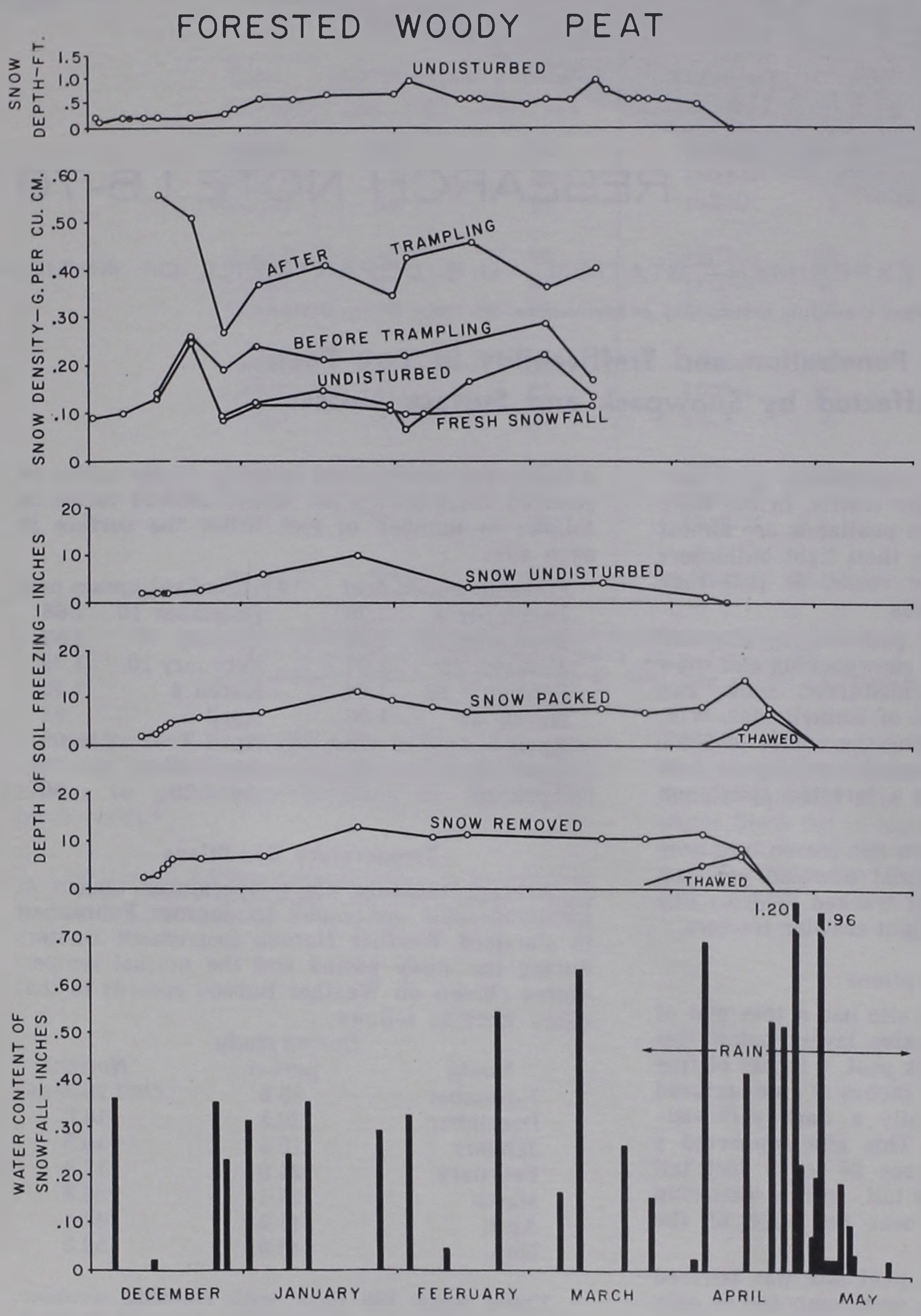

FIGURE 1. — Depth of soil freezing in a shallow forested woody peat as related to snowpack before and after treatment. All precipitation was in the form of snow except for late March, April, and May rains. The timber was medium - site black spruce and tamarack near Rhinelander, Wis.

Instrumentation and Snow Treatment

The snow treatments were started in early December and were carried until the end of the following May. Colman Fiberglas units with thermistors were placed in duplicate stacks at depths of 1½, 4½, 7½, and 10½ inches under the surface of the peat in each site. The units were installed in adjacent comparable areas where snow was (1) undisturbed, (2) packed by trampling after each snowfall, and (3) removed all winter long by shoveling. The instruments were read several times a week from early November before freezeup until the soil was thawed in spring.

The 15½-pound Lake States frost penetrometer was used to obtain supplemental direct readings.

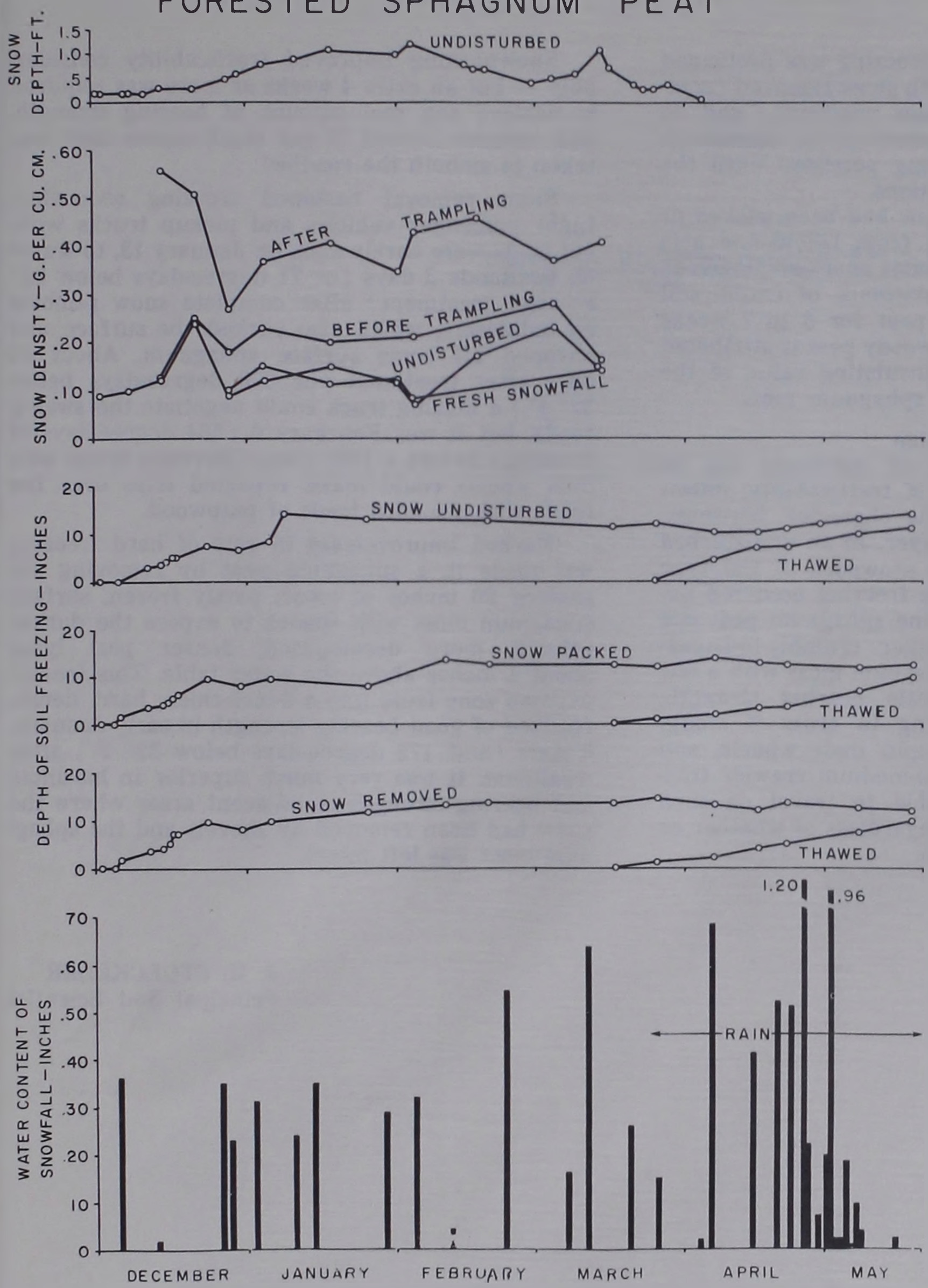

FIGURE 2. — Depth of soil freezing in a fairly deep forested sphagnum peat as related to snowpack before and after treatment. The timber was poor-site stunted black spruce and tamarack near Rhinelander, Wis.

These data were further supplemented by observations in several other swamps where logging operations were underway and where light bulldozers had been used to snowplow and pack temporary winter roads.

Results

The results of the study on these two organic soil sites are given in figures 1 and 2. In spite of spring rain and warming air temperatures, soil freezing under undisturbed snow on the sphagnum moss site lasted into the end of May; at that time 3 inches of frost were still present 11 to 14 inches below the surface. On the woody peat site, soil freezing had completely disappeared by April 12. Some thawing occurred from below in the sphagnum peat, but not in the woody peat.

In the woody peat, soil freezing was prolonged about 12 days in the area with snow removed (compared with undisturbed snow condition) and 20 days where it had been packed. In the sphagnum moss peat, some soil freezing persisted until the end of May under all conditions.

In both peats, where snow had been packed or removed, thawing occurred from below and also from the surface down (zones marked "thawed" in figs. 1 and 2). The persistence of frozen soil in the forested sphagnum peat for 6 to 7 weeks longer than in the forested woody peat is attributed largely to the substantial insulating value of the 18- to 24-inch loose mat of sphagnum moss.

Discussion

The depth of freezing on peatlands can be rather deceptive, in terms of trafficability, unless consideration is given to the character, hardness, and density of the frozen layer. In an undisturbed snow condition and with a snowpack of the type here observed, considerable freezing occurred under the snowpack. But on the sphagnum peat site it occurred in a weak, rather crumbly-to-honeycomb structure of loose sphagnum moss with a low bulk density and very little bearing strength. Wheeled vehicles attempting to cross it would break through the crust, spin their wheels, and bog down. However, light-to-medium crawler tractors or bulldozers were able to travel on such swamps for a few passes, regardless of whether or not the swamps were frozen.

Snowpacking improved trafficability considerably — but an extra 4 weeks or more was required to achieve any real amount of bearing strength, and vehicles tended to get stuck unless care was taken to smooth the roadbed.

Snow removal hastened freezing somewhat. Light passenger vehicles and pickup trucks without loads were barely able, on January 13, to travel on peatlands 3 days (or 71 degree-days below 32° F. after treatment) after complete snow removal by bulldozers, which also packed the surface and stripped off some surface sphagnum. About 10 days after treatment (or 370 degree-days below 32° F.) a logging truck could negotiate the swamp roads, but it was February 6 (584 degree-days of freezing) before a 1953 2-ton Chevrolet truck with dual wheels could make repeated trips over the roads with 4½-cord loads of pulpwood.

Marked improvement in rate of hard freezing was made in a sphagnum peat by removing the surface 20 inches of loose, partly frozen, surface sphagnum moss with spades to expose the darker colored, more decomposed, denser peat lying about 4 inches above the water table. This freshly exposed zone froze into a 5-inch-thick, hard, dense, roadbed of good bearing strength in early January, 8 days (and 172 degree-days below 32° F.) after treatment. It was very much superior in hardness and bearing strength to adjacent areas where the snow had been removed by shovels and the sphagnum moss was left intact.

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